Research Article

Biology and Management of Pomegranate Fruit Borer, *Virachola isocrates* (Lepidoptera: Lycaenidae) through Chemicals and Botanical Extracts

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Abstract | The study was conducted for the management of pomegranate fruit borer, *Virachola isocrates* (Fab.) to investigate the biology and infestation level under field and lab conditions. The experiment was conducted on Randomize Complete Block RCB Design with three replications. For field study, twenty-four trees of pomegranate were selected to which chemicals (cypermethrin, indoxacarb, bifenthrin, lamda-cyhalothrin) and botanicals insecticides (*Azadirachta indica*, *Persicaria hydropiper*, *Eucalyptus globulus* and control (tap water) were assigned in Randomized Complete Block (RCB) Design in three replications. Influence of treatments on mean percent infestation of *V. isocrates* revealed that lamda-cyhalothrin resulted in lowest mean infestation (3.74±0.36) followed by bifenthrin (3.95±0.32), indoaxarb (4.35±0.28), cypermethrin (4.55±0.28), *A. indica* (8.00±0.50), *P. hydropiper* (7.56± 0.27) and *E. globulus* (7.04±0.70). The maximum mean percent infestation (15.57 ±1.24) was recorded from control trees. Maximum yield (16.00±0.49 ha^{-1}) was obtained from lamda-cyhalothrin treated trees while minimum (7.17±0.43 ha^{-1}) was recorded in the control. The developmental period of *V. isocrates* was completed in 34-55 days. The average length of oviposition was 8.84, the larval period was 32.22 days and an average length of pupal was 17.60 days. Adult longevity was 6.58 days. Under laboratory conditions, the highest 100% mortality was caused by lamda-cyhalothrin and cypermethrin after 72hrs followed by *A. indica* seed extract (81.00) and *P. hydropiper* (78.80) when tested under laboratory conditions. Based on the current results, it is concluded that lamda-cyhalothrin and *A. indica* caused high mortality under lab and field conditions, which can be included in future IPM programs.

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Introduction

Pomegranate (*Punica granatum* L.), belonging to Punicaceae family, is a deciduous shrub or a small tree with perennial rootstock (Holland *et al*., 2009). Its area cultivation in Pakistan is 11,153 acres and its annual production is 45,318 tons (Agri-Stat of Pak, 2020). In Khyber Pakhtunkhwa, the production of pomegranate is 2.30 tons (Agri- Stat of Pak, 2018-2019). Pomegranate cultivation in Swat is in its initial phases: though growers are now taking an interest in the commercial production of pomegranate due to its economic value (Khan *et al*., 2017).

Various insect pests (fruit borer, thrips, stem borer and bark-eating caterpillar) attack pomegranate. Among them, the most destructive pest is the pomegranate fruit borer, *Virachola isocrates* (Lepidoptera: Lycaenidae), which attack pomegranate at the flowering stage. This pest is one of the major constraints faced by pomegranate growers in Swat, Khyber Pakhtunkhwa (Khan *et al*., 2017). Studies on pomegranate fruit borer, *Virachola isocrates* have shown that the insect increases primarily on pomegranate fruit under orchard agroecosystem and extreme damage occurs in 30–50 days old fruits, however, the maximum damage is caused by fourth and fifth instar larvae. Most of the eggs are laid singly on newly blooming out leaves, buds, and flowers. The grown-up larvae are 16-20mm long and brownish in color, having standing hair and a body consisting of white patches (Murugan and Thirumurugan, 2001). The peak incidence of the pest is during August in monsoon and more during November and December in winter crop. It attacks the developing fruits and causes heavy losses for growers up to 40 to 90 percent (Shevale and Khaire, 1999).

On a global scale, chemical control is still the primary management option in split of its various disadvantages, such as the non-target effects on beneficial arthropods and insecticides resistance developed by targeted pests (Bionidi *et al*., 2012; Decourtye *et al*., 2013; Gontijo *et al*., 2013; Roditakis *et al*., 2018). For the past 20 years, the effects of pesticides on beneficial arthropods have been the subject of an increasing number of studies, and the potential effects have been reviewed several times (Desneux *et al*., 2007; Thompson, 2003). Two groups of organisms, natural enemies and pollinators, have received the most attention in this regard because of their value in integrated pest management (IPM) (Van *et al*., 1996) and pollination processes (Richards, 1993), respectively. In the same study, pesticides caused predator size reduction, sperm cell distortion, vacuolated spermatocytes in the testis, crumpled follicular epithelium and vacuolization of the germarium in the ovaries. Malformation of ovaries can also occur in parasitoids exposed to IGRs (Schneider *et al*., 2004).

Alternate control measures can be applied for the management of the borer, including botanical insecticides. Natural plant pesticides are safe for environment, natural enemies, other animals and humans. Botanical pesticides also have low and moderate mammalian toxicity (Hassan, 1993). Many researchers reported botanical extracts to have pesticide properties and thus having the potential to be used against many pests (Wu *et al*., 2016). In Pakistan, these extracts are obtained from many plants, including neem seed and leaves, eucalyptus globulus leaves, *Turmeric, henge*, *Datura stramonium*, *Nicotiana tabacum*, garlic and marsh pepper etc. Efficacy of these or other botanical extracts (neem leaf, pungam oil, lluppai oil, neem seed kernel) against *V. isocreates* have been used which successfully reduce the infestation (Kumar and Gupta, 2018). However, cypermethrin, lamda cyhalothrin, bifenthrin and methomyl have been tested against this pest in which lamda chylothrin decreased the infestation comparatively more than other tested treatments (Khan *et al*., 2017). Bio-insecticides have been reported as successful by many researchers and are used to manage several insect pests (Rajput and Tayde, 2017).

Keeping in view the economic importance of the pomegranate fruit borer, the present research was conducted with the aim to determine the biology and infestation level of pomegranate fruit borer under laboratory conditions, and evaluating the efficacy of different insecticides and botanical extracts against pomegranate fruit borer under lab and field conditions. This study will help the pomegranate growers to control the pomegranate borer infestation through safe pesticides.

Materials and Methods

A research study was conducted to determine the efficacy of different chemicals and botanical extracts for managing pomegranate fruit borer at Agriculture Research Institute (ARI) North, Mingora, Swat during the summer of 2018. ARI is located 30° to 35° N latitude and 72° to 74° 6' E Longitude and at an altitude of 984 meters (3,228 ft).

Field experiment

In this experiment, twenty-four trees of variety (Kandahari Anar) were selected from the orchard at the Agriculture Research Institute (ARI) North, Mingora, Swat, Pakistan. Row to row distance was kept 20 feet, and plant to plant distance was 15 feet with an average tree height of 10-15 feet. Eight different treatments were assigned in Randomized Complete Block (RCB) design with three replications. Different insecticides and botanical extracts along with their recommended doses are given below.

Chemical insecticide preparation: The chemical insecticides were brought from the local market, and spray solutions were prepared for foliar application according to their recommended doses with the help of electric balance and graduated cylinder.

Preparation of plant extracts: Neem seeds were brought from the local market and dried. The seed covers were removed for further processing. Leaves of water pepper, and eucalyptus were collected from local fields and shade dried at the laboratory. Then, all the three plant products were milled, and each plant extract was prepared by mixing 50g powder in water in a conical flask to make the final volume of 1 L. Solution for field application (5% concentration) was prepared from the stock solution (Fiaz *et al*., 2012; Mochiah *et al*., 2011; Munir, 2006).

During the entire experiment, 4 sprays were applied at an interval of 10 days using a knapsack sprayer. Control plots were sprayed with tap water. The spray machine and other tools were thoroughly cleaned for each treatment preparation/ application.

Data collection

Fruit damage (%): Post-treatment infestation data were recorded by observing the infested fruits, and their means were calculated with the help of the following formula (Khan *et al*., 2017).

% Fruit Damage= (Number of Damage Fruit)/ (Total Number of Fruit) × 100

Yield data: The fruit yield data were recorded at the time of fruit harvest by picking healthy and mature fruits that were weighed for each of the treatments applied. Further, treatment yield was compared with the control plots. The obtained yield data was first determined in kg and then converted into tons ha^{-1}.

Laboratory experiment

Study on the biology of *V. isocrates* was carried out at the entomology laboratory, ARI Mingora (Swat). Larvae and pupae (ten each) were collected from the infested fruits and were kept in rearing chambers with two fruits per chamber. The emerging male and female insects were differentiated based on their morphological characters. A single pair of newly emerging adults were kept in a glass cage of 500ml, water and 10 % honey solution were supplied to them (as food) in cotton swabs and were covered with mesh cloth. The total eggs laid by the adult (females) were counted, and the duration of egg, larval, pupal and adult stages were noted. The mean temperature and relative humidity during the study period were maintained at 25±2°C and 65±5%, respectively (Kumar, 2017).

Bioassay experiment

A bioassay experiment was carried out at entomology laboratory ARI, Mingora, Swat. The laboratory condition was maintained at 25±2°C Temperature, 65±5% (RH) and 8 hours photoperiod. For this experiment, a chemical solution of lamda-cyhalothrin, cypermethrin and botanical extracts of *Azadirachta indica*, *Persicaria hydropiper* was prepared at recommended dose as mentioned in Table 1. A total of two pomegranate fruits were dipped in the prepared solution for 1 minute, and on each treatment 6 larvae of *Viorachola isocrates* (same size) were exposed to that chemically treated pomegranate fruit in a plastic container having a diameter of 15cm and depth of 10cm. The process was repeated 10 times. Larval mortality data was recorded after 24, 48, and 74 hours (Galdino *et al*., 2011).

Data analysis

The received data was analyzed using computer statistics software STATISTIX. 8.1 version. Means were separated at alpha level=5% after applying LSD test (Gomez and Gomez, 1984).

Results and Discussion

Influence of different synthetic chemicals and botanical extracts on percent infestation of Virachola isocrates

The data (Table 2) showed a statistically non-significant difference in pre-spray data at p< 0.05. However, the percent infestation ranges from 16.8 to 18.56 on all the selected trees. After the treatment application, there was statistically significant difference at p< 0.05 in all the treatments after the application of 1st spray. All the tested treatments reduced the percent infestation of *V. Isocrates*. The minimum (4.26±0.44) percent infestation was recorded in plots treated with lamda-cyhalothrin followed by bifenthrin (4.63±0.37), indoxacarb (4.93±0.37) and cypermethrin (5.33±0.41), cypermethrin, indoxacarb, bifenthrin and lamda-cyhalothrin were not significantly different from each other, but these were significantly different from *Azadirachta indica*, *Persicaria hydropiper* and *Eucalyptus globulus* with (8.93±0.26), (8.53±0.28) and (8.16±0.31) mean percent infestation, respectively. The maximum 17.86 mean percent infestation was recorded in control plots.

A significant difference was recorded after the 2nd spray application among different insecticides and botanical extracts at p<0.05. The lowest (3.8±0.36) mean percent infestation was recorded in Lamda-cyhalothrin, which was not significantly different from cypermethrin, indoxacarb and bifenthrin with (4.86± 0.33) (4.56± 0.31) and (4.16 ± 0.46), respectively, followed by *E. globulus* (7.1± 0.80), *P. hydropiper* (7.63± 0.27), and *A. indica* with (8.16 ± 0.52). The highest 16.56 ± 1.48 mean percent infestation was recorded from control plots.

After the 3rd spray, a significant difference was recorded among different treatments at p<0.05. The lowest 3.63 ± 0.37 mean infestation was recorded from the plot treated with Lamda-cyhalothrin followed by Bifenthrin (3.8 ± 0.36) Indoxacarb (4.16 ± 0.23), and Cypermethrin (4.43 ± 0.32) which was not significantly different from each other. But significantly different from *A. indica*, *P. hydropiper* and *E. globulus* with (7.86±0.57), (7.14±0.29) and (6.64±0.86) mean percent infestation, respectively. From the control plot, the highest (14.76±1.20) mean percent infestation was recorded.

After the 4th spray application, a significant difference at p<0.05 among the chemical and botanical extracts was observed. The minimum mean percent infestation was recorded same for Bifenthrin and Lamda-cyhalothrin (3.23±0.12) followed by Indoxacarb (3.76± 0.24), cypermethrin (3.56 ± 0.17) *E. globulus* (6.26 ± 0.86) *P. hydropiper* (6.6 ± 0.29), and *A. indica* with (7.03 ± 0.75) mean percent infestation. While the maximum mean percent infestation was recorded from control (13.1 ± 1.15).

Table 1: *Different insecticides and botanical extract and their recommended doses.*

S. No.	Treatments	Trade name	Chemical /scientific name active ingredient	Recommended dose
1.	T1	Arrive 10Ec	Cypermethrin	3 ml/lit
2.	T2	Steward 150 Ec	Indoxacarb	0.5ml/lit
3.	T3	Talstar 10Ec	Bifenthrin	2.5ml/lit
4.	T4	Karate 2.5 Ec	Lamda-cyhalothrin	1.5-2ml/lit
5.	T5	Neem seed extract	Azadirachta indica/ Azadirchitin	5%.
6	T6	Water pepper leaf extract	Persicaria hydropiper	5%.
7	T7	Eucalyptus leaf extract	Eucalyptus globulus/ Eucalyptol	5%.
8	T8	Control	--	--

Table 2: *Influence of different synthetic chemicals and botanical extracts on mean infestation of Virachola isocrates on pomegranate fruit.*

Treatment	Pre-Spray	1st spray	2nd spray	3rd spray	4th spray	Mean
Cypermethrin	17.3±0.67	5.33±0.41c	4.86±0.33c	4.43±0.32c	3.56±0.17c	4.55±0.28c
Bifenthrin	17.73±1.23	4.63±0.37c	4.16±0.46 c	3.8±0.36 c	3.23±0.12 c	3.95±0.32 c
Lamda-cyhalothrin	17.65±0.34	4.26±0.44 c	3.8±0.36 c	3.63±0.37 c	3.23±0.26 c	3.74±0.36 c
Azadirachta-indica	17.96±1.14	8.93±0.26 b	8.16±0.52 b	7.86±0.57 b	7.03±0.75 b	8.00±0.50 b
Persicaria hydropiper	18.33±1.28	8.53±0.28 b	7.63±0.27 b	7.14±0.29 b	6.6±0.29 b	7.56±0.27 b
Eucalyptus globulus	18.56±0.18	8.16±0.31 b	7.1±0.80 b	6.64±0.86 b	6.26±0.86 b	7.04±0.70 b
Control	16.8±0.15	17.86±1.20 a	16.56±1.48 a	14.76±1.20 a	13.1±1.15 a	15.57±1.24a
LSD		2.39	2.20	1.94	1.76	2.02

Means followed by a different letter (s) are significantly different from one another at (P≤0.05), using LSD test.

The overall mean percent infestation showed a statistically significant difference at p <0.05. All the applied treatments reduced the *V. isocrates* infestation as compared to the control plot. Data revealed that minimum (3.74 ± 0.36) mean infestation was recorded from Lamda-cyhalothrin followed by Bifenthrin (3.95 ± 0.32), Indoaxarb (4.35 ± 0.28), Cypermethrin (4.55 ± 0.28), *E. globulus* (7.04 ± 0.70), *P. hydropiper* (7.56± 0.27), and *A. indica* with (8.00 ± 0.50) mean percent infestations. The maximum (15.57 ± 1.24) mean percent infestation was recorded from the control plots. The synthetic chemical applications were not significantly different from each other but were significantly different from botanical extracts and control. Similarly, the botanical extracts were not significantly different from each other but were significantly better than control.

Influence of different chemicals and botanical extracts on pomegranate yield (t ha^{-1})

Yield data recorded in tones ha^{-1} from different chemicals and botanical extracts treated plots of pomegranate orchard (Figure 1) showed a significant difference at P <0.05. The maximum yield (16.00 ± 0.49t ha^{-1}) was recorded from plots treated with Lamda-cyhalothrin followed by Bifenthrin (15.33 ± 0.29 t ha^{-1}), Cypermethrin (15.1 ± 0.58 t ha^{-1}), Indoaxarb (14.86 ± 0.58 t ha^{-1}), *A. indica* (12.27 ± 0.27 t ha^{-1}), *P. hydropiper* (11.97 ± 0.29 t ha^{-1}) and *E. globulus* with (11.34 ± 0.66 t ha^{-1}). While the minimum (7.17±0.43 t ha^{-1}) yield was recorded from control plots. Plots treated with synthetic pesticides did not differ significantly from each other, however, these were significantly better as compared to the botanical extracts and control plots.

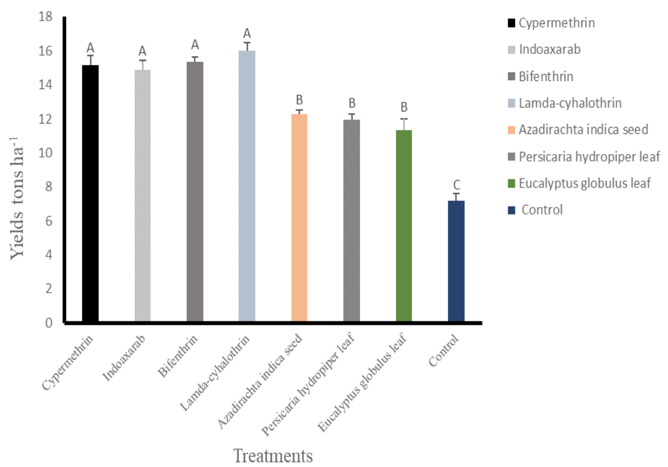

Figure 1: *Influence of different chemicals and botanical extracts on pomegranate Yield (t ha^{-1}).*

Developmental period (Days) and adult longevity of Virachola isocrates record on Kandahari anar variety under laboratory conditions

The data (Table 3) showed that reared *V. isocrates* laryae emerged from eggs singly on tender leaves and stems during the experiment under lab conditions. The data further revealed that the eggs period lasts 7-10 days with an average of 8.84 days. The recorded larval period was 18-46 days, with a mean duration of 32.2 days. Pupation occurs in soil and its pupal period lasts for 8-32 days with a mean duration of 17.6 days. The life cycle was completed within 34-55 days with an average duration of 45.3 days. Adult longevity ranges from 4-7 days with an average of 6.58 days.

Influence of different synthetic insecticides and botanical extracts on mortality (%) of the 4th instar larvae of Virachola isocrates under laboratory conditions

Results (Table 4) showed a significant difference at (P ≤ 0.05) in mean percent mortality of larvae after 24, 48 and 72 hours after exposure to different synthetic insecticides and botanical extracts.

Table 3: *Developmental period (Days) and adult longevity of pomegranate fruit borer Virachola isocrates grown on Kandahari Anar Variety under laboratory conditions.*

Developmental stages	Duration (Days)	Mean ±SE
	Range	
Eggs period	7-10	8.84±0.95
Larval period	18-46	32.22±7.08
Pupal period	8-32	17.60±4.99
Adult	6-8	6.58±0.85
Total life cycle	34-55	45.36±3.8

Means followed by a different letter (s) are significantly different from one another at (P≤0.05), using the LSD test.

Table 4: *Influence of different synthetic insecticides and botanical extracts on Mortality (%) of the 4th Instar larvae of Virachola isocrates under laboratory conditions.*

Treatments	Doses	Mean % mortality after		
		24 Hrs	48Hrs	72Hrs
Lamda-cyhalothrin	1.5-2ml/lit	54.50 a	83.78a	100.00a
Cypermethrin	3 ml/lit	52.52 a	82.12a	100.00a
Azadirachta indica seed	5%	26.80 b	57.60b	81.00b
Persicaria hydropiper leaf	5%	23.80 b	53.40b	78.80b
Control	Water	0.00 c	0.00c	0.00c
LSD		3.9075	4.4884	3.1566

Means followed by different letter (s) are significantly different from one another at (P≤0.05), using LSD test.

After 24hr, non-significant differences were recorded between Lamda-cyhalothrin and cypermethrin but these were found significantly different from *Azadirachta indica* seed extracts, *Persicaria hydropiper* leaves in percent mortality of the larvae. The maximum mortality (54.50) was caused in larvae exposed to Lamda-cyhalothrin followed by Cypermethrin (52.52), *A. indica* seed extract (26.80) and *P. hydropiper* (23.80). The mean percent mortality increased after 48hr in all the treatments (except control). Maximum mean percent mortality was 83.78 recorded from Lamda-cyhalothrin, which is statistically similar to Cypermethrin (82.12), followed by *A. indica* seed extract and *P. hydropiper* leaves (57.60 and 53.40), respectively. After 72 hrs, the highest mean percent mortality was not significantly different for lamda-cyhalothrin and cypermethrin (100.00) followed by *A. indica* extract (81.00), *P. hydropiper* leaves (78.80).

In the present study, different synthetic insecticides (lamda-cyhalothrin, bifenthrin, indoxacarb and cypermethrin) and botanical extracts (*E. globulus*, *P. hydropiper* and *A. indica*) were tested against *V. isocrates* under field conditions. While under laboratory conditions the biology of *V. isocrates* was studied, and synthetic insecticides and botanical extracts were tested for percent mortality of *V. isocrates* (Larvae).

The field study results showed a statistically significant difference in percent infestation of *V. isocrates* in all applied treatments. All the treatments reduced the *V. isocrates* infestation as compared to control. Data revealed that minimum mean percent infestation was recorded from Lamda-cyhalothrin followed by Bifenthrin, Indoaxarb, Cypermethrin, *E. globulus*, *P. hydropiper*, and *A. indica* with mean percent infestations. The maximum mean percent infestation was recorded from the control plots. The synthetic chemical applications were not significantly different from each other. However, Lamda-cyhalothrin was found most effective in minimizing the percent infestation. Similar results were reported by Khan *et al*. (2017), who tested Bifenthrin, Cypermethrin, Methomyl, and Lambda-Cyhalothrin in pomegranate orchard against *V. isocrates* and concluded that Lamda-cyhalothrin is most effective. The botanical extracts were more effective than control but their efficacy was less than synthetic insecticides. Corresponding results are stated by Kumar and Gupta (2018) where they used synthetic insecticides and bio-pesticides and found botanical extracts as less effective than synthetic insecticides (Kumar and Gupta, 2018). Neem oil (3%), neem seed kernel extract (5%) and neem cake extract (5%) were found moderately effective against pomegranate fruit borer by Karuppuchamy *et al.* (2001), which is similar to our results. The efficacy of *A. indica* against *Virachola isocrates* is also reported by Bhut *et al.* (2013).

In the present study, yield (tones ha^{-1}) obtained from different treated plots were significantly different. The maximum yield was recorded from plots treated with lamda-cyhalothrin followed by bifenthrin, cypermethrin, indoaxarb, *A. indica*, *P. hydropiper* and *E. globulus*. In contrast, the minimum yield was recorded from control plots. The corresponding findings were reported by Bhut *et al.* (2013), who obtained significantly higher pomegranate yield from plots treated with insecticides than other treatments (5% neem seed kernel extract). The yield of plots treated with botanical extracts was significantly higher than control plots.

In this experiment, the biology of the *Virachola isocrates* was studied under laboratory conditions and the observation revealed that *V. isocrates* lay their eggs singly on tender leaves and stems during the experiment at laboratory conditions. The incubation period was recorded at 8.84 days, while the total larvae duration was observed at 32.2 days. Pupation occurs in soil/fruit and its pupal mean duration was recoded at 17.6 days. Adult longevity at 6.58 days, while the total life cycle was observed 45.3 days. The outcome of our research work was in contrast with findings of Khan (2016) by studying study the biology of *V. isocrates* on guava, and his results showed that the incubation period, larval period, pupal period of this borer ranged from 8-10, 17-46, 7-33 days, respectively. The total life cycle was completed within 30 to 60 days. The current results are also agreed with Kumar (2017), where pomegranate fruit borer mean larval period was recorded 32.9 ± 2.38 days, pupation period 10.25 ± 0.10 days, total developmental period 63.92±2.87 days, adult female longevity 10.28 ± 0.20 days and male longevity period 8.26 ± 0.14 days on pomegranate. Similarly, the biology of *V. isocrates* was examined by Khandare *et al.* (2018) on pomegranate and concluded that the total developmental period last for 67.00 ± 8.67 days. The larval period of pomegranate fruit borer varies from 24 to 38 days (33.2 ± 1.10) days on Citrus (Chhetry *et al*., 2015). (Kabade and Gangawane, 2015) reported that larval duration of pomegranate fruit borer ranged from 33 to 38 days with mean of 35.3 ±1.88 days and pupal period mean was 14.5 ± 2.7 (10-18) days on Emblica officinalis.

Furthermore, larvae of *V. isocrates* were exposed to insecticides and botanical extracts treated fruits for finding the effectiveness of the treatments and percent mortality of the borer. Results showed significant difference in the percent mortality of *V. isocreates*. After 24hr, non-significant differences were recorded between Lamda-cyhalothrin and Cypermethrin but these were found significantly different from *Azardirachta indica* seed extract, and *Persicaria hydropiper* leaves in percent mortality of the larvae. The mean percent mortality increased after 48hrs in all the treatments (except control). After 72hrs, the highest mean percent mortality was the same (100%) for Lamda-cyhalothrin and Cypermethrin followed by *A. indica* seed extract (81.00) and *P. hydropiper* (78.80). The effectiveness of Cypermethrin against *H. armigera* was reported by (Martin *et al*., 2000). The findings are in line with Khan *et al*. (2017), who used Cypermethrin, Lamda-cyhalothrin, Bifenthrin, and Methomyl in pomegranate field against *V. isocrates* and concluded that Lamda-cyhalothrin was most effective in reducing infestation caused by *V. isocrates*. The results regarding the efficacy of botanical extracts are in line with (Sisay *et al*., 2019) who used *A. indica*, *E. globulus* and *N. tabacum* against *Spodoptera frugiperda* and reported that *A. indica* was most effective among the tested botanical extracts. Similarly, the efficacy of botanical extracts (Neem, Datura, and Bitter apple) against *Chrysoperla carnea* larvae has been reported by (Khaliq *et al*., 2014).

In overall both experiments (lab and field), synthetic insecticides decreased the percent infestation and caused high mortality compared to the botanical extracts. The botanical extracts showed a sufficient response in decreasing the percent infestation compared to control but were less effective than synthetic chemicals. The highest yield in (tones ha^{-1}) was obtained from insecticides treated plots.

Conclusions and Recommendations

The synthetic chemicals and botanical extracts both performed better in reducing the mean infestation of pomegranate fruit borer on pomegranate fruit; however, the lowest mean infestation was recorded in Eucalyptus globulus leaf extract. Synthetic chemicals caused the highest percent mortality as compared to the botanical extracts in lab conditions. *V. isocrates* completes its whole life cycle within 34-55 days. Maximum yield was obtained from plots treated with synthetic chemicals followed by botanical extracts, while the minimum was recorded from the untreated plot (control). To avoid or minimize synthetic insecticide use, botanical insecticides should be incorporated in management programs because they have less or no impact on the environment and the natural ecosystem. Based on the current studies, further studies on the side effect of these botanical extracts are recommended. The farmer should be informed through extension efforts for promoting these management techniques.

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Novelty Statement

The Novelty of this research is to study the biology of *Virachola isocrates* for the first time in Pakistan under laboratory conditions with its management through safe insecticides which will help future management studies of Pomegranate fruit borer.

Author's Contribution

Shahid Sattar: Design the experiment and review the paper.
Abdul Latif: Conducted research.
Fazal Maula: Analyzed the data.
Imtiaz Khan and Said Hussain Shah: Wrote the paper.
Asim Iqbal: Review the paper.

Conflict of interest
The authors have declared no conflict of interest.

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